Chapter 13

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CASE STUDIES:
LESSONS LEARNED AND CONCERNS

HRTD
Human Resources
Training & Development

Learning Objectives

As result of this lesson students will have a better understanding of:

1. Various failure scenarios involving emergency diesel generators and their support systems.
2. The significance and safety implications of individual licensee LERs and other documents regarding EDG issues.
3. The potential reliability impact of things beyond the EDG's boundaries such as lightning, underground cable faults, grid anomalies, switchyard failures, etc.
4. The potential unintended consequences of events in the vicinity of the EDG, such as maintenance/cleaning activity or fire suppression system actuation.

Learning Objectives (continued)

5. Possible shortcomings in the licensee's operational or maintenance procedures for EDG's and their support systems.

6. The likely effectiveness of licensee corrective actions for EDG failures.

7. "Aging" issues and other ongoing concerns regarding EDG systems.

EDG Starting Failures

Defective Air Start Motors

- Twenty incorrectly assembled Ingersol-Rand series 89 ASMs
- Factory technician installed elastomeric o-rings instead of metallic seals, because he failed to use parts "pick list"
- Used in EMD and FM PC engines. The first few air starts would have been satisfactory, until o-ring abraded. Then the engine would have either started too slowly or failed to start.
- Defective units shipped to 7 sites: Beaver Valley, Clinton, Davis-Bessee, Millstone, Surry, Quad Cities and Nuclenor*
- Refer to 10CFR21-0095, 20 October 2008

EDG Starting Failures (continued)

Malfunctioning Speed Switch Circuits

- Malfunctioning power supply (dc) in the EDG gauge board panel caused electrical noise (ac ripple) in speed switch circuit, making the switch change state prematurely, which prevented EDG start.
- Caused by failed or degraded filter capacitor in the dc power supply. In the previous 7 years there had been 10 similar cases where speed switch issues had prevented start.
- Electrolytic capacitors degrade with time and dc power supplies for control equipment need to be checked periodically to verify ripple voltage is within limits.
- See Information Notice 2010-23.

EDG Starting Failures

Painting Activities and Cleaning Agents

- *Numerous* cases involving impact to engines, generators, pumps, radiation monitors, fire detection/suppression systems, etc.
- Three reactor trips. Summary in ADAMS under ML091600446
- One drop of paint on fuel rack prevented EDG start. IN 2009-14
- Cleaning solvent damaged 16 safety-related switches. IN 93-76
- Undiluted muriatic acid being used to clean EDG room floor severely damaged electrical controls and circuits.
- Common cause: Work control shortcomings… lack of training, and inadequate supervision, communications, or procedures.

Controls Related Failures

Spurious Shutdown (Design Oversight)

- Some EDGs use starting air for critical control functions including pneumatic control logic for non-emergency protective trips.
- Several plants were found to have starting air compressors on non-class E1 power circuits.
- Loss of air pressure from leaks during EDG run first un-bypassed the protective trips normally bypassed in emergency mode and ultimately resulted in generator trip.
- Need to assure reliability of EDG support systems thru long runs
- Refer to IN 98-41

Controls Related Failures (continued)

Inadvertent EDG Start

- Starting a very large load (aux feed pump) caused E1 bus V dip to 80%, thereby starting the EDG. The system worked normally.

Load Sequencer Failure

- ESF load sequencer upgraded from electro-pneumatic to solid state microprocessor type. Hi magnetic environment ⇨ failure.

Improperly Diagnosed Governor Failures

- Numerous governors reported as defective were actually not.
- Power-type relays used to provide control input to governor had erratic contact resistance. Application required "control" relays.

Controls Related Failures (continued)

Defective Governor Drive Couplings

- Failure of flexible drive couplings between engine gear train and governor, used for speed sensing.
- Caused by use of Isoprene couplings instead of Neoprene, needed for its strength and resistance to the chemicals present.
- The manufacturer was unable to distinguish between materials!
- Several plants with Transamerica Delaval engines got bad parts.
- Ironically, Part 21 report from 23 years previous documented similar failures, and the original change to Neoprene.
- New failures covered in 10 CFR 21-0090, 16 September 2005

Controls Related Failures (continued)

Ignored Circuit Breaker Problem

- Following auto reactor trip, a non-safety related circuit breaker did not open to isolate a fault, due to lack of control power to its trip circuit.
- Licensee records verified control power indicating lights on the breaker had been out for approximately one year!
- Previous IN 1991-78 and IN 2007-34 emphasized importance of having control power to safety *and* non-safety related breakers.
- See IN 2010-09 and ADAMS info (Accession No. ML100880412)

Controls Related Failures (continued)

Defective Governor DRU IC Chips

- Four Woodward governors failed (3 in test and 1 in service), indicated by inability to adjust frequency (engine RPM)
- Caused by defective CMOS IC chip in digital reference unit (DRU), from internal corrosion and de-lamination of the package.
- DRUs produced Nov 2000 - Nov 2005 had potentially defective IC chips by the same manufacturer and needed to be replaced.
- FM reported first failure. Reference 10 CFR 21-0088 (2004)
- Subsequently 10 CFR 21-0091 was issued on 23 January 2006

Engine Mechanical Failures

Crankcase Explosions (Recap)

- Chapter 12 covered the problem of 13 crankcase explosions in Cooper-Bessemer KSV engines
- Licensees (owners group) and manufacturer eventually found and corrected the multiple causes
- Problem exacerbated by routine fast start-load surveillance tests
- Could have been prevented by an effective program of lube oil sampling and analysis
- Could have been prevented by an oil mist monitoring system

Engine Mechanical Failures (continued)

Defective Diesel Cam Roller Bushings

- Involved fuel pump cam roller bushings for FM OP engines shipped to 15 nuclear plants
- Fabricated with leaded brass, instead of the specified bronze, so they wear out quickly (in one case < 55 hours)
- Results in shorter pump stroke ⇨ decreased power output, etc.
- FM implemented inspections and supplier certification of cam hardness 30 July 2001. Prior cam roller bushing are suspect.
- See 10 CFR 21 Notification by FM, dated 9 April 2007

Engine Mechanical Failures (continued)

Defective Nordberg Engine Valve Seats

- Potential for Nordberg valve seat inserts to 'drop' from the bore of the cylinder head into the cylinder, causing damage to piston, cylinder head, valves, cylinder liner, exhaust manifold and turbo.
- Root cause was design error in the amount of interference fit for inlet and exhaust valve seat inserts.
- Defect was not apparent until failures occurred outside the U.S.
- Brunswick and McGuire notified to take corrective action.
- See 10 CFR 21 Notification dated 13 June 2006.

Engine Mechanical Failures (continued)

Engine Damage Caused by Maintenance

- Routine lube oil analysis found high level of Cr in EDG oil. Unit declared inoperative. Inspection found scored cylinders, rings. (Two days previous, similar damage found in another EDG.)
- Investigation found sand (aluminum oxide) in the combustion air intake manifold of both engines.
- Water side of combustion air intercoolers had been sandblasted to remove scale, without the air side being well protected.
- Three years prior, sand was found in the air side of intercoolers after sandblasting (fortunately before reassembly). Obviously, no lesson was learned from that. See IN 90-80.

Fire Protection Issues

Deaths From Inadvertent Discharge of CO_2 Fire Protection Systems

- CO_2 extinguishes fire by smothering it (displacing Oxygen)…
- A CO_2 system protecting the engine room will stop the EDG if its combustion air is from same space (instead of being ducted)
- Numerous cases of unintended discharge of CO_2 systems. Since 1975, that has resulted in a total of 63 deaths and 89 injuries.
- This sobering statistic points out the need for licensees to take measures to prevent impact to personnel and equipment. Some have changed these systems to manual release only…
- For more information see IN 99-05

Fire Protection Issues (continued)

Unintended Discharge of Halon 1301 Fire Suppression Systems

- Unlike CO_2, Halon 1301 and newer "clean agent" gaseous fire suppression systems extinguish fires only, not people**…**
- Like CO_2, it can stop the engine if combustion air is taken from same room.
- IN 2007-23 covered an incident in which a Halon 1301 manual release ("pull") station was mistaken for a fire alarm pull box...
- IN 97-82 reported a Halon system triggered by a camera flash…
- Some fire alarm control equipment can be spoofed by RF from hand held communications radios...

Fire Protection Issues (continued)

EDG Building Fires Resulting from Improper Roof Repairs

After 21 hours of a 24-hour EDG endurance run (surveillance test), combustible roofing material on the EDG building caught fire near the diesel exhaust pipe penetration (roof stack) area.

- Root cause was improper installation of roofing materials during re-roofing (asphalt paper in contact with exhaust sleeve, which reaches approximately 900^{o}F)…
- Again, any work in the vicinity of EDG requires administrative oversight and inspection. All roof work should include a fire watch and fire extinguishers… See IN 2007-17. Also, IN 2002-27 gives firefighting lessons learned from variety of events.

Engine Cooling Failures

Fouled Heat Exchangers

- Two tandem EDGs powering a generator tripped out on high jacket water temperature, in quick succession.
- Investigation found the jacket water heat exchangers were fouled. That reduced the ability of the engines to reject heat and would have led to failure during an emergency run near design load.
- Heat exchangers cleaned and maintenance interval reduced.
- Reduced cooling capacity from heat exchanger fouling or high water temperature can be a problem when on-site water used.

Engine Cooling Failures (continued)

Water Leaking Into Cylinder

- During a pre-run check after being idle 7 days, the licensee's engine roll-over ("bar") procedure found several pints of water in a cylinder due to a gasket leak. This averted severe damage.
- Five years before a similar engine "save" had occurred there.
- The utility began the procedure a decade earlier, after they had an engine severely damaged during start due to hydraulic lock.
- Engine "roll" before a run is not a universal practice but should always be done after an extended idle period…
- The licensee was San Onofree. See IN 91-62

Fuel Oil / Lube Oil Related Failures

Leaks Caused by Fatigue Cracking

- Plants have experienced leaks in fuel oil, lube oil, water piping.
- Many were the result of fatigue cracks in welded joints, induced by normal engine vibration.
- Some involved FM OP engines produced at a time when partial-penetration welded joints used in the fabrication process…
- Problem not unique to OP (≈200 weld joints). FM has since switched to full penetration welds, ASME Section III, Class 3.
- Licensees need to be aware of the potential for fatigue cracking of *any* manufacturer's EDG components, especially as running hours increase. See IN 98-43.

Fuel Oil / Lube Oil Related Failures (continued)

Cold Fuel Oil Concerns

- NRC has found multiple sites with fuel specifications that do not adequately assure proper cold weather characteristics.
- Pour point and cloud point criteria were inappropriate for the potential lowest temperatures at the sites…
- Most concern is for sites with above-ground fuel tanks/piping without heat tracing powered from a safety source.
- A common-mode failure. Temp cushion of 10°F recommended. Routine runs may not uncover problem (warmer day tank used).
- See IN 94-19.

Fuel Oil / Lube Oil Related Failures (continued)

Cylinder Failures Caused by Improper Fuel Oil

- Following 110 percent load surveillance tests, engine clattering was noted, and the engine shut down.
- Inspection revealed two badly overheated pistons, scored liners, and badly worn connecting rod and wrist pin bearings.
- All fuel injectors coated with paraffin and several cylinders were either not firing or were producing only small amount of power. Confirmed by records of extremely low and high exhaust temps.
- Analysis of fuel oil disclosed non-specification fuel. Draining tanks and replacing fuel corrected the cause of this problem. This is yet another case supporting fuel analysis and trending.

Fuel Oil / Lube Oil Related Failures

High Pressure Fuel Leak

- During an EDG post-maintenance test run, a supervisor noticed fuel spraying from the high pressure line for cylinder 1R.
- Engine shut down, line replaced. Problem was common.
- Engine manufacturer developed a double wall fuel pipe for replacement, one with more gradual bends.
- Fire hazard, as 1R adjacent to exhaust and right bank turbo!
- Again, walk-around inspections before, during, and following runs are important. This case could have caused a serious fire.

Fuel Oil / Lube Oil Related Failures

Lube Oil Incompatibility with Low-S Fuel (One step before ULS)

- During pre-operational testing of a newly installed EDG, wide crankcase pressure fluctuations and other anomalies noted.
- Internal inspection revealed heavy carbon deposits on pistons and rings, scuffing of cylinder walls (in this and other EDGs).
- Root cause was fuel oil-lube oil incompatibility. Supplier had delivered fuel with 500ppm (0.05%) S, to meet new EPA regs. Prior fuel was 3000ppm (0.3%) and lube contained additives to neutralize sulfuric acid it would produce. Unreacted additives were the problem. Engines rebuilt ⇨ LS-compatible mineral oil
- See IN 96-67. This case revealed a synthetic oil characteristic…

Fuel Oil / Lube Oil Related Failures (continued)

Synthetic oils contain diester additives to improve solubility of oil additives. In diesels with low oil sump temperatures, water may accumulate in sump because temperature is too low to vaporize it. Water may cause hydrolysis of the diesters and the resulting acids would react with calcium in additive to form insoluble compounds (soaps) that can clog filters and degrade diesel performance...

The next step for fuel oil occurred in 2010, when Ultra-Low Sulfur (ULS) containing 15ppm (0.0015%) maximum S was required for all *non-road uses*. Some suppliers began to deliver ULS in 2006 and California required ULS diesel for <u>all</u> users effective 1 June 2006.

The following material is taken from IN 2006-22 and other sources.

Special Concerns for ULS Diesel Fuel (ULSD)

ULSD (15ppm maximum Sulfur) has the potential to impact diesel engine performance in a number of ways. This is very significant due to its many facets and because all licensees are affected.

Several diesel fuel properties other than sulfur concentration are changed as a result of the move to ULSD. Any of the following characteristics may adversely affect diesel engine performance:

Energy Content

- Processing reduces volumetric energy content at least 1.2%
- Drop in energy output can reduce instantaneous output rating
- Fuel consumption will increase due to lower energy content

ULS Diesel Fuel (continued)

Fuel Particulate Build-up Increases

- Additives to compensate for lower lubricity can react or become unstable in storage, increasing fuel particulates that may foul or plug filters and fuel injection equipment.
- Some licensees report more particulates (potential filter impact)

Fuel System Seal Leaks

- Non-nuclear industry experience with ULSD shows increased incidence of fuel system leaks at elastomeric o-rings.
- Evidence to date suggests the problem is linked to a reduction in the aromatics content of ULSD, which affects seal swelling.

ULS Diesel Fuel (continued)

Compatibility with Lubricating Oil

- See previous discussion for IN 96-62. The concerns for ULSD mirror those for LSD.

Microbial Growth

- Diesel fuel desulfured by hydrocracking (versus hydrotreatment) may have more propensity for microbial growth, due to having an increased concentration of n-alkanes (linear molecules).

Incompatible Metals

- Copper and zinc are incompatible with ULSD because both are oxidative catalysts that will accelerate the formation of sediments, gels, and soaps (ASTM D975, Appendix X2.7.2).

ULS Diesel Fuel (continued)

Lubricity

- The processing required to reduce sulfur to 15 ppm also removes naturally-occurring lubricity agents in diesel fuel.
- Refiners treat the diesel fuel with additives on a batch to batch basis to ensure adequate lubricity. Therefore, receipt of ULSD with inadequate lubricity is possible, but unlikely.

These potential issues with ULS diesel are well understood and can be addressed in a straightforward way by licensees. Biodiesel fuel oil poses some issues of its own that may be harder to deal with. That topic will be covered next, based primarily on IN 2009-02.

Biodiesel Fuel

In 2008 the American Society for Testing and Materials approved a change to ASTM D975-08a, *Standard Specification for Diesel Fuel Oils*. Effective in early 2009, No. 2 petrodiesel fuel oil could have up to 5% biodiesel blend *without being so labeled*. This may be problematic for EDG engines, for the following reasons:

Cleaning Effect

- B5 has a solvent effect that loosens accumulated sediment in fuel oil storage tanks, possibly clogging filters. If fact, it will actually dissolve some kinds of paint if left on long enough.
- Licensees can clean tanks, upgrade filters, and check filters more often before any use of B5 (if they are even aware of it).

Biodiesel Fuel (continued)

Water

- B5 contains suspended water particles from its manufacturing process. The water will, in time, fall out of suspension and form "dirty water" in the fuel oil storage tank, which eventually leads to the formation and growth of algae.
- Licensees can use a moisture dispersant and biocide, add a fuel-water separator to the system, and keep tanks topped off.

Biodegradation

- B5 is biodegradable, and the presence of water, heat, oxygen, and other impurities accelerate the degradation of the fuel supply. Storage for longer than 3-6 months not recommended.

Biodiesel Fuel (continued)

Material Incompatibility

- Brass, bronze, copper, lead, tin, and zinc in tanks and fittings may accelerate the oxidation process of B5, creating fuel insolubles or gels and salts. Licensees should avoid using zinc linings, copper pipes and fittings, or brass regulators with B5.
- Licensees should verify that elastomeric materials, such as hoses, gaskets, and O-rings are compatible with B5.

Temperature Protection

- Biodiesel components have higher cloud points than petroleum components and they vary considerably with the source of the biodiesel feedstock, which is not even specified in B5 blends.

Combustion / Ventilation Air

Engine Exhaust / Room Cooling Exhaust Recirculation to Intake(s)

- EDG ratings are based upon specific maximum engine room and combustion air inlet temperatures, having non-contaminated combustion air with proper oxygen content, and also specific maximum for intake air depression and exhaust back pressure.
- Licensees have had problems with combustion exhaust and/or room cooling exhaust recirculation back into the room or the combustion air intakes.
- One licensee could not take advantage of an engine up-rating mod without first eliminating up to 15 percent recirculation of engine and ventilation exhausts back into the air intakes for engine combustion and cooling air.

Site Switchyard and Distribution

Single-Failure and Fire Vulnerability of Electrical Safety Buses

- NRC inspectors discovered an electrical protection and metering circuit which, if damaged, could electrically lock out redundant safety buses and prevent re-energization from *any* source.
- A fire-induced cable fault or watt-hour meter failure would be interpreted by the protection system as an electrical bus fault on both safety busses. Relay logic would lock out both.
- This violated the 10 CFR 50 Appendix A, GDC17 "I-R-T" criteria. Licensee separated the protective circuits, removed the meter.
- Inspectors found similar single-point vulnerabilities at five other plants and concluded such problems were likely widespread.

Site Switchyard and Distribution (continued)

Large Transformer Failures

- Industry operating experience has indicated an increasing trend in large transformer failures.
- Transformer failures have resulted in 8 declared plant events from January, 2007, to February, 2009, making them the 2nd leading reason for such declarations.
- Root cause evaluations show these events are often the result of ineffective implementation of transformer maintenance.
- Reference only: IEEE Std. C57.140-2006, *Guide for Evaluation and Reconditioning of Liquid Immersed Power Transformers*.
- See IN 2009-10.

Site Switchyard and Distribution (continued)

Submerged Electrical Cable Failures…

- NRC began detailed review of underground ac/dc cables in 2006, after moisture-induced failures occurred at several plants. Staff identified 23 LERs from 1988-2004 describing such failures.
- GL 2007-01 was issued to gather information on inaccessible or underground power cable failures for all cables that are within the scope of the Maintenance Rule. See also IN 2010-26.
- Concern licensees are *not maintaining safety-related power or low voltage cables in their designed and tested environment*.
- When submergence found, corrective actions typically involve the removal of water, the installation of a sump pump or repair of the drainage, and cable evaluation or testing as appropriate.

Grid Reliability Concerns

LOOP/SBO More Likely in the Summer

NUREG-1784 (2003) showed switchyard / grid-related LOOP events occurred mostly in summer. A new INEL report, NUREG/CR-6890, confirmed the earlier data regarding seasonal risk trends:

- SBO risk was twice as high during the summer periods between 1997-2004 (as a result of 22 summer, 2 non-summer LOOPs).
- LOOP frequency is more than twice as high during the summer
- Probability of LOOP after reactor trip is greater during summer
- All categories of LOOP events (plant, switchyard, grid, weather) had higher frequencies during the summer period.

These have implications for plant operations. See IN 2006-06

Grid Reliability Concerns (continued)

Grid Reliability Impact on Plant Risk

On 14 August 2003 the largest U.S power outage occurred in the NE states and parts of Canada. Nine U.S. NPPs tripped, of which eight lost offsite power. (All had power back to switchyard < 7 hrs.)

- NPPs are designed to cope with a LOOP event through the use of onsite power supplies but LOOP events are considered to be precursors to SBO. An increase in the frequency or duration of LOOP events increases probability of SBO and/or core damage.
- In response to grid reliability concerns, the NRC issued Generic Letter 2006-02: "Grid Reliability and the Impact on Plant Risk and the Operability of Offsite Power." Licensees were directed to provide substantial data relative to grid concerns. *Some of its goals are listed on the next slide…*

Grid Reliability Concerns (continued)

- Better communications between the NPP operator and the Transmission System Operator (TSO) regarding grid-plant status.
- TSO use of analysis tools to determine the impact of the loss or unavailability of various transmission system elements.
- The establishment of protocols between NPP's and TSO's, especially relating to communications.
- Real-time NPP operator knowledge of grid status, especially whether loss of the NPP will result in a LOOP event.
- Real-time TSO knowledge of the NPP status, especially grid-risk-sensitive maintenance activities.
- Determine if more NPP operator training is needed for the above

The Ticking Clock: Aging Issues for EDGs

Post-TMI Load Creep

- This may not seem an aging issue but the design basis of a plant can become outdated due to changes.
- As safety equipment is modified, replaced, or updated EDG loads often change.
- Other factors such as ULS diesel fuel oil affect EDG calculations.
- The issues described by IN 93-17 and the subsequent TI 2515/176 regarding EDG design basis adequacy are also relevant.

The Ticking Clock: Aging Issues (continued)

Underground Fuel Tanks

- *All UG steel fuel tanks will eventually leak*. It's only a question of "when" that will occur. Fiberglass tanks have seismic issues.
- Coatings and *well-maintained* cathodic protection will delay the inevitable but licensees must be vigilant for tank problems, as water and rust will severely compromise EDG fuel oil.
- This is yet another reason to have an effective program of fuel oil analysis and trending in place.
- Pressure testing of the fuel system during refueling, to verify integrity, is also recommended.

The Ticking Clock: Aging Issues (continued)

Replacement Parts Unavailability

- This is obviously impacting all NPP systems, not just EDGs. It has been exacerbated by plant license extensions beyond the original 40 years. (IEEE 387-1995 now addresses EDG aging.)
- For EDGs the concerns include legacy engine governors, as well as circuit breakers, relays, and parts for engine accessories and support systems.
- Fortunately there are upgraded engine governors available.
- Substitution of other electrical and mechanical components may be necessary. This raises qualification issues.

The Ticking Clock: Aging Issues (continued)

Electric Cable Insulation Degradation

- Submerged cables were previously discussed. NRC Generic Letter 2007-01 had a broader perspective, *all underground or inaccessible cables within the scope of 10 CFR 50.65.*
- It asked licensees to provide a history of cable failures. Further, it asked them to describe their cable inspection, testing, and monitoring programs for inaccessible / underground cables.
- Cross-linked polyethylene insulated cable (Type XLP) has been an electrical industry concern for decades, whether dry or wet. XLP is no longer manufactured and deserves special attention.
- See NUREG/CR-7000 (BNL-NUREG-90318-2009), "Essential Elements of an Electric Cable Condition Monitoring Program.

The Ticking Clock: Aging Issues (continued)

Accumulated Impact of Unnecessary Fast Starts of EDGs

- Some licensees still persist in performing fast starts with immediate heavy loading, a topic that has been extensively discussed in this Manual.
- They are unnecessarily damaging their EDGs and taking years off the useful life of these systems.
- This is particularly troublesome in view of the license extension for many plants.
- They need to understand the new direction of IEEE 387-1995 and RG 1.9 Rev 4, as well as previous NRC actions extending back to Generic Letters 84-15 and 94-01.

The Ticking Clock: Aging Issues (continued)

The Human Factor: The Heavy Loss of Experienced Personnel

- A high percentage of those who entered the nuclear industry in its earlier years are retiring.
- Their departure is impacting the experience level at licensee facilities and also within the NRC itself.
- That poses a challenge for both regulators and licensees as the nuclear power industry has to gear up for the new wave of plant construction and operations.
- It cannot be allowed to impact NPP safety. The real challenge is how to assure that…

Industry EDG Activities

- Owner's Groups for Cooper-Bessemer, Fairbanks-Morse, EMD, and Cooper Industries/ Enterprise Group keep abreast of EDG problems through "Alert Lists."
- Support organizations include Electric Power Research Institute (EPRI) and the Institute of Nuclear Power Operations (INPO).
- These disseminate EDG operational and failure data to Owner's Groups through Nuclear Plant Reliability Data System (NPRDS).
- INPO also maintains an equipment failure data base (EPIX).
- World Association of Nuclear Operators (WANO) serves a similar global role.

END OF CHAPTER 13